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ARRANGEMENTS FOR ENERGIZING SOLENOID VALVES OF AN ELECTROHYDRAULIC VALVE-TIMING SYSTEM IN A CONTROLLABLE MANNER

Field of the Invention

The present invention is directed to an arrangement for supplying current to the solenoid valves of an electro-hydraulic valve-timing system of an internal combustion engine in a controllable manner.

Background Information

In known electrohydraulic valve-timing systems, solenoid valves are assigned to gas-exchange actuators. The solenoid valves are energized in order to control the flow of hydraulic oil to and from the gas-exchange actuator. In this context, it is known to provide a two-stage voltage supply for the solenoid valves. An inrush voltage is supplied by an inrush voltage source, and a holding voltage is supplied by a holding-voltage source, the inrush voltage being greater than the holding voltage. The actuation of the solenoid valve in response to the application of the inrush voltage leads to a rapid acceleration of the valve body. In this way, the valve's inertia is reduced. Following a free-running phase subsequent to the actuation by the inrush voltage, the solenoid valve is actuated by the holding voltage. The holding voltage is of sufficient magnitude to reliably bring the valve body into the end actuation position of the valve, and to hold it there. However, compared to the inrush voltage, the current consumption in the holding phase is lower. As a result, there is also less self-heating of the valve. The solenoid valves can be actuated independently of one another for the duration of an inrush current time by an inrush current that corresponds to the applied inrush voltage, and for the duration of a holding current time by a holding current that corresponds to the applied holding voltage. Thus, the duration of actuation

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of the solenoid valve is derived from the inrush current time, the time subsequent thereto for the free-running phase, and from the holding current time. In this context, the solenoid valve can be designed both as a normally-open as well as a normally-closed valve. If the solenoid valve is designed as a normally-open valve, then it interrupts a fluid path when energized, while a valve designed as a normally-closed valve clears a fluid path when actuated. In this context, one holding voltage line and one inrush voltage line are provided for each solenoid valve, the holding voltage line connecting the solenoid valve to the holding voltage source and the inrush voltage line connecting the solenoid valve to the inrush voltage source. Moreover, a ground lead leading from the solenoid valve to ground is provided, having one ground lead disconnector for switchably disconnecting the electrical connection between the solenoid valve and ground.

In the above-described arrangement, besides the ground lead disconnector, for each solenoid valve, a changeover switch is also necessary to connect the solenoid valve alternatively to the inrush voltage line or to the holding voltage line.

To actuate a gas-exchange valve, the solenoid valves assigned to this gas-exchange valve are driven. In the process, the controlled actuation of the changeover switch and of the ground lead disconnector is required to drive a solenoid valve. The electric power supply to the particular solenoid valve is switched via the ground lead disconnector, while the inrush voltage or the holding voltage is alternately applied to the solenoid valve via the changeover switch.

A gas-exchange valve is typically controlled via two solenoid valves; one determines the supply of hydraulic fluid into a working chamber, and the other controls the discharge of the hydraulic fluid out of the working chamber. If an internal

combustion engine has four gas-exchange valves (two intake valves and two exhaust valves) per cylinder, then eight solenoid valves and thus sixteen separately controllable switches are needed just to control one cylinder. An equivalent number of driving signals for actuating the solenoid valves must be generated time-synchronously to move the crankshaft.

It is an object of the present invention to reduce the outlay required for circuitry and for control of solenoid valves.

Summary

An arrangement for supplying current to the solenoid valves of an electrohydraulic valve-timing system of an internal combustion engine in a controllable manner has solenoid valves assigned to the gas-exchange actuators. A two-stage supplying of voltage is provided for the solenoid valves, namely the supplying of an inrush voltage from an inrush voltage source, and the supplying of a holding voltage from a holding voltage source. In this context, the inrush voltage is greater than the holding voltage. The solenoid valves may be actuated independently of one another for the duration of an inrush current time by an inrush current that corresponds to the applied inrush voltage, and for the duration of a holding-current time by a holding current that corresponds to the applied holding voltage. For each solenoid valve, one inrush voltage line and one holding voltage line are provided, which connect the solenoid valve to the inrush voltage source and to the holding voltage source, respectively. From each solenoid valve, a ground lead leads to ground, a ground lead disconnector being provided in the ground lead for switchably disconnecting the electrical connection between the solenoid valve and ground.

In accordance with the present invention, a solenoid valve group is formed from a plurality of solenoid valves. Inrush voltage

lines leading to the solenoid valves of a solenoid valve group have a common inrush-voltage circuit section, and a voltage disconnector is provided in the common inrush-voltage circuit section for establishing the switchable electrical connection between the inrush voltage source and the solenoid valves of the solenoid valve group.

As a result of this arrangement, only one single switchable voltage disconnector needs to be provided for the solenoid valves of the solenoid valve group to establish the connection to the inrush voltage. This single voltage disconnector replaces the changeover switch that is provided for each valve. If the voltage disconnector is switched through, then the inrush voltage is applied to all solenoid valves of the solenoid valve group. The actual energizing of the solenoid valve with the inrush current derived from the inrush voltage is accomplished by the actuation of the individual ground lead disconnectors assigned to the solenoid valves. A solenoid valve is energized with inrush current when the voltage disconnector of the corresponding solenoid valve group is closed and, at the same time, when the corresponding ground lead disconnector of the solenoid valve is likewise closed. Due to the existence of the ground lead disconnector, the solenoid valves within the solenoid valve group continue to be individually controllable.

Thus, the present invention makes it possible to reduce the number of required switches. Along with the reduction in the number of switches, the outlay for controlling the switches is also correspondingly reduced. Due to the presence of a common inrush-voltage circuit section, the outlay for circuit wiring is also reduced.

In accordance with one example embodiment of the present invention, the holding-voltage line is designed to permanently supply the solenoid valves of at least one solenoid valve group

with holding voltage. In this context, the holding voltage lines leading to the solenoid valves have a common holding voltage section. This measure reduces the outlay for circuit wiring.

In accordance with another example embodiment, the voltage disconnector of a solenoid valve group connects the common inrush voltage section to the common holding voltage section of this solenoid valve group at a contact point. In this context, a blocking diode is provided in the common holding voltage section between the holding voltage source and the junction point. It blocks the current flow from the junction point to the holding voltage point. A common line for supplying the corresponding solenoid valve with inrush voltage and with holding voltage leads from the junction point to the solenoid valves of the solenoid valve group. This measure further reduces the outlay for circuit wiring. The inrush voltage and holding voltage may be supplied, in part, over the same line. If the voltage disconnector of a solenoid valve group is interrupted, then the holding voltage is applied to the solenoid valves. If the voltage disconnector is closed, then the inrush voltage is applied to the solenoid valves. The diode between the holding voltage source and the junction point source prevents current from flowing from the inrush voltage source to the holding voltage source and, thus, an undesired shunting. This measure as well reduces the outlay required for cabling or circuit wiring.

The solenoid valves of a solenoid valve group are energized by the inrush current derived from the inrush voltage when the voltage disconnector is closed and, at the same time, when the ground lead disconnector assigned to the individual valve is likewise closed. A solenoid valve is actuated by the holding current derived from the holding voltage when the voltage disconnector of the solenoid valve group is disconnected and the

ground lead disconnector assigned to the corresponding solenoid valve is closed.

In accordance with one example embodiment of the present invention, the solenoid valves of a solenoid valve group are selected in such a way that the inrush-voltage actuation times do not overlap with the holding-voltage actuation times. This measure ensures that when it is necessary to supply one solenoid valve of the solenoid valve group with inrush voltage, that it is not necessary to supply another valve with holding voltage. Alternatively, either the inrush voltage or the holding voltage is applied to the voltage supply side of the solenoid valves. If there is no overlapping of the holding current times and the inrush current times, then the voltage disconnector may be suitably actuated to effect that the voltage level required at the particular instant is applied to the voltage side of the solenoid valves.

In a classic valve-timing mechanism, the opening angular ranges of the gas-exchange valves over the crankshaft angle are, at a maximum, 240° crankshaft angle. This considers both the opening times of the intake valves as well as of the exhaust valves. Accordingly, at a maximum, this is proportionally 33% of an engine's working cycle of over 720° crankshaft angle, so that it is easily possible to combine a plurality of solenoid valves into one solenoid valve group, without the occurrence of any corresponding overlapping.

In accordance with one example embodiment of the present invention, the ground lead disconnector of the solenoid valves is switchable in a clocked cycle. In this context, the make-to-break ratio is devised in such a way that when inrush voltage is supplied, the average current flow resulting from the clocked operation corresponds to the holding current derived from the holding voltage. Thus, by the timed switching of the ground

lead disconnector, power may also be supplied using a current corresponding to the holding current when the inrush voltage is applied on the voltage-supply side. This measure is particularly advantageous when, within solenoid valves assigned to one solenoid valve group, an overlapping results between inrush-voltage actuation times and holding-voltage actuation times. However, it may also be utilized to reduce the number of switching operations of the voltage disconnector and to partially allow the inrush voltage to be applied on the voltage supply side even when it would actually suffice for just holding voltage to be supplied. In accordance with another example embodiment of the present invention, on the ground connection side, each solenoid valve has a feedback line which connects the ground connection of the solenoid valve to the inrush voltage source. In this context, a diode is connected in the feedback line. It blocks a current flow from the inrush voltage source to the ground connection of the solenoid valve.

The advantage of this example embodiment of the present invention is that the currents flowing in the coil of a solenoid valve are able to be quickly reduced once the ground lead disconnector is opened. Simply stated, current is fed back via the feedback line to the inrush-voltage source. The diode situated in the feedback line prevents current from flowing from the inrush voltage source via the feedback line to the solenoid valve and, from there, to the holding voltage source. If a solenoid valve is actuated by an inrush current because the voltage disconnector was closed, then, in response to opening of the ground lead disconnector, the decaying coil current may flow back to the inrush voltage source. In between applications of in-rush current and holding current to the solenoid valve, the so-called free-wheeling or free-running phase is generated. In this free-running phase, the ground lead disconnector of the corresponding solenoid valve is opened. Similarly, a rapid extinguishing of current results, so that the solenoid valve is

quickly moved back at the end of the holding phase predefined by the holding current time. If, in response to the application of holding voltage, the ground lead disconnector of a solenoid valve is opened, the still present coil current may only be fed back via the feedback line to the voltage source, which is at a higher potential than the holding voltage source. The result is a rapid decay of the coil current.

In accordance with one example embodiment of the present invention, first and second solenoid valves are provided, the first solenoid valves being closed in a de-energized state, and the second solenoid valves being opened in a de-energized state. As an example, each gas-exchange actuator has a first and a second solenoid valve. Each cylinder of the internal combustion engine has, e.g., at least one intake valve and at least one exhaust valve, each of the intake and exhaust valves being able to be actuated by a gas-exchange actuator. A complete electrohydraulic valve actuation is accomplished by this arrangement.

In accordance with one example embodiment of the present invention, all solenoid valves of the gas-exchange actuators assigned to one cylinder of the internal combustion engine are combined into one solenoid valve group.

By combining into one solenoid valve group, all solenoid valves which are assigned to one cylinder because of their allocation to the gas-exchange actuators form a solenoid valve group for which it is ensured that the time periods during which the solenoid valves are actuated by inrush voltage do not overlap with those periods during which they are actuated by holding voltage.

Given a reduced number of control elements and a reduced outlay for actuation, such an arrangement renders possible a valve

control that is free of overlap times, even in the context of internal combustion engines having a large number of cylinders.

In accordance with one example embodiment of the present invention, for at least two cylinders of the internal combustion engine in each case, the solenoid valves assigned to the intake valves are combined into a first solenoid valve group, and the solenoid valves assigned to the exhaust valves are combined into a second solenoid valve group. Compared to an approach where all solenoid valves of one cylinder of the internal combustion engine are combined into one solenoid valve group, this makes it possible to further reduce the number of controllable switches and the corresponding outlay for control lines, without the occurrence of overlap times. For example, in the case of a four-cylinder engine, which, in each case, at one cylinder, has two exhaust valves and two intake valves having two solenoid valves each, a design approach involving individual solenoid valves requires 32 ground lead disconnectors and also 32 changeover switches between the inrush voltage source and the holding voltage source. When the four solenoid valves of the intake valves and the four solenoid valves of the exhaust valves are combined into one solenoid valve group each, compared to the previously required eight changeover switches, only two voltage disconnectors are required; the number of corresponding switches and necessary diodes is likewise reduced correspondingly.

If for two cylinders, eight solenoid valves which are assigned to the intake valves and eight solenoid valves which are assigned to exhaust valves of the cylinders are combined into one solenoid valve group, then only 1/8 of the voltage disconnectors are needed, as are any existing diodes in feedback lines. The result is a further reduction in the outlay for design and assembly. If the solenoid valves of more than two cylinders are combined into solenoid valve groups, then a further reduction in the outlay for design and assembly may be

achieved. However, in some instances, one then has to accept the occurrence of overlap times during which, on the one hand, it would be necessary to supply one solenoid valve of a solenoid valve group with inrush voltage and, on the other hand, to supply another solenoid valve of the same solenoid valve group with holding voltage. However, three suitably selected cylinders of one six-cylinder engine may be combined into one solenoid valve group still without any or with only very few overlap times. If overlap times occur, then a timed switching of the ground lead disconnectors must be utilized for these time periods. Nevertheless, in such an embodiment, the advantages of reduced costs because of the reduced number of required diodes and required voltage disconnectors may outbalance the disadvantages of the resulting requirement for a timed switching of the ground lead disconnectors.

In accordance with one example embodiment of the present invention, the at least two cylinders are selected from the cylinders of the internal combustion engine in such a way that no overlapping of inrush-voltage actuation time and holding-voltage actuation time occurs within the solenoid valve group.

In accordance with one example embodiment of the present invention, one cylinder group is formed in each instance from a plurality of cylinders of the internal combustion engine. For one cylinder group, all first solenoid valves - which are closed in a de-energized state - of the intake valves are combined into a first solenoid valve group, and all first solenoid valves - which are closed in a de-energized state - of the exhaust valves are combined in a second solenoid valve group, and all second solenoid valves - which are closed in a de-energized state - of the gas-exchange valves are combined into a third solenoid valve group. It is customary for a gas-exchange actuator, thus for an intake valve or an exhaust valve, to have a first solenoid valve, which is closed in a de-energized state and which

controls the inflow of pressurized hydraulic fluid into the working chamber of the hydraulic actuator. Situated at the exhaust side of the hydraulic actuator is a second solenoid valve that is opened in the de-energized state. This design ensures that the working chamber of the gas-exchange actuator is unpressurized in response to de-energized solenoid valves. In this context, all cylinders of an internal combustion engine may be combined into one cylinder group. However, in accordance with one alternative example embodiment, it may also be provided for at least two cylinder groups to be formed. In such a case, one cylinder group would then contain all cylinders of one cylinder bank. Another example embodiment provides for forming at least two cylinder groups, each of a plurality of cylinders, the cylinders of one cylinder group being selected in such a way that, within the solenoid valve groups of the cylinder groups, no overlapping of inrush-voltage actuation time and holding-voltage actuation time occurs. In this context, each cylinder group may contain the same number of cylinders.

Such an embodiment of the present invention makes it possible to combine a large number of solenoid valves into one solenoid valve group, without any overlapping of inrush-voltage actuation times and of holding-voltage actuation times occurring. For example, in the context of a four-cylinder engine, every eight first solenoid valves of the intake valves, every eight first solenoid valves of the exhaust valves, and every sixteen second solenoid valves of all gas-exchange actuators are combined in each instance into one solenoid valve group. Thus, for a four-cylinder internal combustion engine, only three voltage disconnectors and only three decoupling diodes are needed between the holding voltage and the inrush voltage. Together with the 32 ground lead disconnectors that this yields, in a four-cylinder internal combustion engine of this kind, only 35 switches are needed, and only 35 driving signals need to be generated. This also substantially reduces the necessary number

of timing channels on the part of the control unit and the outlay required for the processing unit of the control unit.

In accordance with one alternative example embodiment of the present invention, the need may also be completely eliminated for a holding voltage source. As a result, the device makes do with one single voltage source. The outlay is further reduced. This is achieved in accordance with the present invention in that, in order to supply the holding voltage, the voltage disconnector is switched in a clocked cycle, the make-to-break ratio being selected in accordance with the ratio between the holding voltage and the inrush voltage. In this context, the solenoid valves of one solenoid valve group are selected in such a way that no overlapping of inrush-voltage actuation times and holding-voltage actuation times occurs.

Brief Description of the Drawings

Figure 1 shows an example embodiment of an arrangement in accordance with the present invention for energizing four solenoid valves, which are assigned to two gas-exchange actuators.

Figure 2 shows a schematic representation of the formation of a solenoid valve group of all solenoid valves assigned to the gas-exchange valves of a cylinder.

Figure 3 shows a schematic representation of an example embodiment having two valve groups, the first valve group combining the solenoid valves of intake valves, and the second valve group combining the solenoid valves of exhaust valves of two cylinders.

Figure 4 shows a schematic representation of an example embodiment in which first solenoid valves and second solenoid

valves of gas-exchange actuators are combined in solenoid valve groups that differ from one another.

Detailed Description

In Figure 1, an example circuit arrangement in accordance with the present invention is shown for two gas-exchange valves Z1E1, Z1E2. Figures 2 through 4 have been simplified in comparison to the circuit arrangement shown in Figure 1 to the effect that the shared wire routing of holding-voltage line and of inrush-voltage line via shared circuit sections, as well as the feedback line, along with the diode disposed therein, are no longer shown. The purpose of Figures 2 through 4 is to illustrate how the solenoid valves of the individual gas-exchange actuators are combined into solenoid valve groups. In this context, the wiring configuration and the use of shared circuit sections are possible in the example embodiments of Figures 2 through 4 in the same way as in Figure 1.

In the following descriptions of the figures, as well as in the figures themselves, U_A denotes the inrush voltage and U_H the holding voltage source. The gas-exchange actuators are designated with respect to their property as intake valve or as exhaust valve and their assignment to cylinders, and are each schematically represented. Their designation includes the primary symbol Z, with a subsequent numeral to designate the cylinder to which they are assigned, the subsequent letter E or A, which describes the assignment to the intake or exhaust valves of the corresponding cylinder, and of a subsequent numeral which distinguishes among the intake valves and among the exhaust valves of a cylinder. The example embodiments of Figures 1 through 4 are based on an internal combustion engine which has two intake and two exhaust valves for each cylinder. Each gas-exchange actuator is assigned a first solenoid valve denoted by M1 and a second solenoid valve denoted by M2.

Figure 1 shows an arrangement in which the two intake valves Z1E1 and Z1E2 of first cylinder Z1 each have a first solenoid valve M1 and a second solenoid valve M2. The two first solenoid valves M1 and the two second solenoid valves M2 are combined into one valve group. Each of solenoid valves M1, M2 is assigned a ground lead disconnector, which is situated in the electrical connection of the particular solenoid valve M1, M2 to ground 12. From a junction point 13, a holding-voltage line 14 leads in each instance to one of solenoid valves M1, M2, so that each of the solenoid valves is connected via a holding-voltage circuit section 14 to junction point 13. A diode 16 is connected in series between junction point 13 and holding-voltage source U_H in such a way that it prevents current from flowing into holding voltage source U_H. Moreover, a shared inrush-voltage section 17, which, via a controllable voltage disconnector 18, connects junction point 13 to inrush voltage source U_A, leads to the junction point. From ground-side connection 19 of a solenoid valve M1, M2, one feedback line 20 leads in each case back to inrush voltage source U_A, it being possible for circuit sections to be jointly used here as well. Disposed in each feedback line 20 is a diode 21, which prevents a short circuit current from inrush voltage source U_A to ground 12 via ground lead disconnector 11, or from inrush voltage source U_A via feedback line 20 and corresponding solenoid valve Ml, M2 and holding voltage section 14 back to junction point 13.

To energize a solenoid valve within a half-bridge circuit, it is necessary to close voltage disconnector 18 and ground lead disconnector 11 assigned to solenoid valve M1, M2. Merely closing voltage disconnector 18 does not produce any current flow through a solenoid valve M1, M2. Thus, it is possible to interconnect all solenoid valves of the group via the one voltage disconnector 18 of the solenoid valve group. Solenoid valves M1, M2 may each be energized just by closing ground lead disconnector 11.

The inrush voltage is switched in via voltage disconnector 18 to be able to start the solenoid valves in a highly dynamic manner. However, the inrush voltage should be active only until the valve armature undergoes its acceleration. After that, following a free-running phase, the transition to a holding current is required to keep the solenoid valve open to a specific degree. On the one hand, energy savings are thereby achieved and, on the other hand, the solenoid valves are prevented from overheating. In this context, the extent to which the solenoid valves are energized may be reduced by opening ground lead disconnector 11 assigned to the solenoid valve or by opening voltage disconnector 18. In order for a solenoid valve M1, M2 to be energized by a holding current derived from the applied holding voltage, to the extent that the inrush voltage is not needed for another solenoid valve, voltage disconnector 18 is opened. On the voltage-input side, holding voltage U_H is then applied to the solenoid valves. In response to closing of ground lead disconnector 11, the corresponding solenoid valve is then energized by the holding current.

If an overlapping between energizing a solenoid valve Ml, M2 with holding current and energizing with an inrush current occurs when inrush voltage U_A is applied to the voltage-side end of another solenoid valve M1, M2 of the same valve group, then, by the clocked driving of ground lead disconnector 11 of solenoid valve M1, M2 which is to be operated with the holding current, given a closed voltage disconnector 18, an average current flow is generated corresponding to the holding current. In this context, the make-to-break ratio between the closed and open ground lead disconnector corresponds to the ratio of the holding voltage to the inrush voltage.

An alternative example embodiment of the present invention is provided by omitting diode 16 and holding-voltage source U_H. In such a case, the holding voltage is achieved by the suitable

timed switching of voltage disconnector 18. In this context, the make-to-break ratio of the switch corresponds to the ratio between the holding voltage and the inrush voltage. In such a case, there must not be any overlap time between the inrush-voltage actuation times and the holding-voltage actuation times.

In a simplified schematic representation, Figure 2 shows the grouping of solenoid valves M1, M2 of the two intake valves Z1E1 and Z1E2, as well as of the two exhaust valves Z1A1 and Z1A2 of a first cylinder Z1 into a shared valve group. Shown in the drawing, as well as in the other Figures 3 and 4, is gas-exchange actuator Z1E1, Z1E2, Z1A1, Z1A2, in each instance below the two solenoid valves M1, M2 assigned to it. A ground lead disconnector 11 leading to ground 12 is assigned to each of solenoid valves M1, M2 of the solenoid valve group. From holding-voltage source U_H, shared holding-voltage section 15, as well as holding-voltage sections 14 lead to solenoid valves M1, M2. In this context, diode 16, which blocks current flow toward holding-voltage source U_H, is situated in the shared holding-voltage section 15.

Figure 3 illustrates one example embodiment of the present invention where intake valves Z1E1, Z1E2, Z2E1 and Z2E2 of the two cylinders Z1 and Z2 are combined into a first valve group and are, therefore, connected to first voltage disconnector 18a, while solenoid valves M1, M2 of exhaust valves Z2A1, Z2A2, Z1A1 and Z1A2 of the two cylinders Z1 and Z2 are combined into a second valve group and are connected to second voltage disconnector 18b. The two voltage disconnectors are connected to inrush-voltage source U_A. Each solenoid valve group is also connected to holding-voltage source U_H, and, for reasons of simplicity, for each cylinder Z1, Z2, a separate holding voltage source U_H is shown, which is protected by a diode 16 from backward flow of current from solenoid valves M1, M2. Assigned to each of the solenoid valves is a ground lead disconnector 11

which is used to establish the switchable electrical connection to ground 12.

Figure 4 shows another example embodiment where solenoid valves M1, M2 are combined into three valve groups which differ from one another and which each have an assigned voltage disconnector 18a, 18b, 18c. The exemplary embodiment of Figure 4 is shown for two cylinders Z1, Z2, which have gas-exchange valves Z1E1, Z1E2, Z1A1, Z1A2, Z2E1, Z2E2, Z2A1 and Z2A2. In the arrangement of Figure 4, still other cylinders may be added in the same manner to the valve groups, but, for the sake of clarity, only two cylinders Z1, Z2 are shown in the drawing. In the example embodiment shown in Figure 4, first solenoid valves M1 are assigned to different solenoid valve groups than second solenoid valves M2. Second solenoid valves M2 of all gas-exchange valves Z1E1, ... Z2A2 are combined into a common valve group, which is connected via third voltage disconnector 18c to inrush-voltage source. Moreover, first solenoid valves M1 of intake valves Z1E1, Z1E2, Z2E1 and Z2E2 are combined into a second valve group and are connected via second voltage disconnector 18b to inrush-voltage source. The third valve group is formed from first solenoid valves M1 of exhaust valves Z1A1 ...Z2A2 and is connected via first voltage disconnector 18a to the inrush voltage source.